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ASTRONOMY AND ASTROPHYSICS

Giant Stellar Arcs as the imprint of Precessing Gamma Jets by Gamma-Ray Bursts

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Abstract. Precessing Gamma Jets, originated by Neutron Stars or Black Holes, may blaze to the observer leading to Gamma Bursts (GRBs) and Soft Gamma repeaters (SGRs). The thin gamma jet is born either at Supernova (SN) like events mostly at the cosmological distances, like GRB, or at nearer accreting binary system, like SGRs. The collimated gamma jet Comptonized by the ultrarelativistic inner electron pairs jets (hitting thermal photos) spins (because of the pulsar) and precedes (because of a companion or accreating disk) in helical and spiral nebular shapes. Its cumulative spray may eject and sweep gas creating nebular rings and plerions and, after long time, partiall HI supershells. Their consequent gravitational fragmentation may lead to characteristic star formation in giant arcs, which might be just the relic imprints of the earliest peaked GRBs and the late steady SGRs precesing jet emissions. Relic stellar rings and arcs may inform, by present morphology on the jet binary eccentricity and its time evolution. Their lifetime and occurrence may probe the Supernova-GRB connection.

Key words: GRB, Jet, Inverse Compton, SGR, star formation

1. Introduction

We consider in the present paper the evidence for strong beaming of GRB events. One piece of these data is the shape of the possible stellar relics of these events: the arc-shape stellar structures were suggested to be the plausible remnants of Gamma Ray Bursts or related events (Efremov et al. 1998, Efremov 1999a,b). We suggest that Gamma Ray Burst (GRBs) and Soft Gamma Repeaters (SGRs) are neither standard candle nor isotropic (Fireball) explosions. A unified jet model may explain both of them as the strong blazing of a light-house, spinning and precessing gamma jet (Fargion 1998b, 1999). Such jets (born by black holes (BH) or Neutron Star (NS) in binary or accreting system) while at their maximal output, as during Supernova like events ejecting, rarely, in axis blaze as GRBs. At late, less powerful but nearer, stages these jets (as SGRs in our Galaxy and the LMC) may blaze the observer by similar extreme beaming ($\Omega < 10^{-8}$) and while precessing it may lead to apparent variable gamma fluence, respectively comparable, for GRBs, to a few solar masses annihilation or, for SGRs, to a Supernova luminosities. Interaction of Gamma-ray bursters (GRB) jets with the interstellar matter may lead to rapid afterglows tails (in X and optical bands) as well as to later formation of sweeped gas supershells, rather similar to those formed by common explosive SNe, yet generally more energetic and collimated into conical or hour-glass shapes. (Updated examples of such cumulative spraying of a variable nebula (Egg Nebula, NGC 2261), may be found respectively easily on net ($antwrp.gsfc.nasa.gov/apod/image/hst_eggneb_big.gif$); ($www.psiaz.com/polakis/n2261/n2261.html$).The inner Nebula jet up-down spraying explain the observed twin conical shape and the evolving nebula luminosity. See also the recent Protostar jet spraying along HH-34 on net ($www.eso.org/outreach/press-rel/pr-1999/phot-40b-99-preview.jpg$). Such gas ejections at comparable or larger scales are suggested here as source for the largest nebular supershells, for which there is no realistic formation nor after multiple SNe events, neither by cloud impacts. The samples of such supershells are mentioned in Efremov et al.(1998), and Loeb and Perna (1998). The comparison of some parameters of the supershells formed by long standing supply of energy (like SNe and O-stars) and by single explosive event were considered by Efremov et al. (1999). However, some properties of suggested stellar remnants of GRBs are difficult to explain with either mechanism and we consider here the possibility of their formation after action of beamed emission and/or long-standing multi-precessing jets.

In the present paper we summarize the arguments that the giant stellar arcs (at least the multiple ones) did form by the beamed powerful explosion and/or by the long standing jets from these objects. The only known such objects are GRBs and SGRs. If these giant arcs of stars and clusters are indeed remnants of GRB explosions (and

their long-standing activity), their properties might give important constrains on the nature of GRB. The open angle of arcs being dozens degrees, could point to the beamed at this angle radiation and the presence of a non-negligible binary companion. We imagine within the cone jet a more narrow fine structured jets (arc secs) whose precession angle may be open few tens of degree and variable because of the disk or companion interactions or asymmetric accreting disk. We conclude that the properties of arcs are compatible only with their formation after the feeding of the narrow multi-precessing jets from GRB. We believe (Fargion and Efremov;2000) that such multi-precession jet system is a scale invariant property linking microjets (few solar masses) to heavier AGN blazars (million to billion solar masses).

2. The need for beaming

The need for GRBs beaming is wide: the GRB luminosities are over Eddington, the event peaked structure is chaotic, the spectra is non-thermal, the energy budget may exceed two solar masses annihilation (Fargion 1994, Fargion, Salis 1995-98, Fargion 1998-1999). The spinning and precessing periodicity is hidden into the short GRB observational window; indeed the periodicity did arise in Soft Gamma Repeaters as soon as more data have been available. As it was demonstrated recently, many light curves of the GRB might be explained by the blazing of multi-precessing gamma jets (Fargion 1994-1995-1999). A wider GRBs data sheet, as for SGRs data would show the spinning periodicity of GRBs and possibly the quasi periodic behaviour of the parental binary system. Behind the energy problem stand (to isotropic fireball models) the puzzling low probability to observe any close GRB as GRB980425 at a negligible cosmic distance (38 Mpc) along with a couple of dozen of far and very far events seen by BeppoSax in last two years.

Statistical arguments (Fargion 1998, 1999) favor a unified GRBs model based on blazing, spinning and precessing thin jet. The far GRBs are observables at their peak intensities (coincident to SN) while blazing in axis to us within the thin jet very rarely; consequently the hit of the target occurs only within a wide sample of sources found in a huge cosmic volume. In this frame work the GRB rate do not differ much from the SN rate. Assuming a SN-GRB event every 30 years in a galaxy and assuming a thin angular cone ($\Omega < 10^{-8}$) the probability to be within the cone jet in a (10^{11}) galactic sample within our present observable Universe volume ($z \leq 2$) during a nominal 10 sec GRB duration is quite small: ($P < 10^{-3}$). However a precessing gamma jet whose decaying scale time (approximated power law $\sim t^{-1}$) is nearly twenty thousand of seconds (Fargion 1998-1999) fit naturally the observed GRB rate.

Also, if these jets have complicated spinning and multi-precession spirals, they could explain many (or all) features of the light-curves of GRB, especially the recent observed periodic tails in SGR and rarest (20%) mini-X-GRB precursors (Fargion 2000). The possibility that precessing Gamma jets are source by their interactions onto a red giant relic shell of the Twin Ring around SN1987A has been proposed since 1994 (Fargion & Salis 1995b, 1995c). It has been also been suggested (Fargion & Salis 1995) that the additional transient presence of a paraboloid thin arc along one of the twin ring of SN1987A, the mysterious "Napoleon Hat" observed on 1989-1990, was the evidence for a thin long projected jet interacting tens parsec away from the SN1987A toward us. The jet pressure would also accumulate gas and form dense filamentary gas.

The possibility of the origin after the GRB explosions was suggested (Efremov et al. 1998) for the multiple giant arcs of stars and clusters, described long ago by Hodge (1967) in the LMC and NGC 6946. Two of these arcs in the supershell LMC4 region in the LMC were in a first approximation explained by Efremov and Elmegreen (1998) as the results of the multiple SNe near their centers, yet later on it was demonstrated that their origin after the GRB explosions is much more probable (Efremov 1998, 1999a,b; Efremov and Elmegreen, 1998). Here we argue and conclude that the most probable cause of the giant arc nature is indebted to the GRBs and SGRs precessing jets nature.

A few more stellar arcs are known in other galaxies and their open angles, as well as for the LMC arcs, are always smaller than ~ 90 degree, what was suggested to be connected with the beaming of the GRB explosion (Efremov, 1999), and as we suggest here, it is to be indebted to the driving force of a binary companion.

3. The giant stellar arcs

Giant arcs of the luminous stars and young clusters have been known for a long time in the region of the supershell LMC4 in the LMC. The most obvious was noted by Westerlund and Mathewson (1966) and since then generally called "Constellation III". These authors ascribed the origin of the arc (which they considered to be the southern rim of the HI supershell) to a super-Supernova explosion. This arc and two others in the same region were sketched by Hodge (1967), who also found similar arcs in NGC 6946, recently confirmed by picture given by Larsen and Richtler (1999). Earlier a number of even larger arcs and rings of clusters were suspected in different galaxies by Hayward (1964), most of which are however too large and plausibly just a chance configurations.

The multiple arcs in the LMC contains young clusters of about the same age (Brown et al., 1998, Efremov and Elmegreen, 1998) and the same is true for the arcs in the NGC 6946 (Elmegreen et al., 1999). Along with the strictly circular shape and giant sizes (150 - 300 pc in radii) these coeval ages prove beyond any doubt the coherent origin of objects in arcs. The double small arcs are suspected

in M83 along with two single arcs of clusters and altogether a dozen of single arcs was noted in galaxies mainly in Sandage-Bedke atlas (Efremov, 1999a, 2000b), so the arcs are rather rare structures. This is possibly related to their short lifetime as the correlated configurations and also to the projection effects.

The region of supershell LMC4 was considered the best manifestation of triggered self-propagated star formation (Dopita et al. 1985). However, there are serious difficulties with this interpretation because there was no evidences for the age gradient across the supershell (Olsen et al. 1997; Braun et al. 1997). Recently, Efremov and Elmegreen (1998) suggested that two well-shaped arcs in this region formed by triggered star formation in gas that was swept-up by centralized sources of pressure. The strictly circular shapes of both arcs are the strongest evidence for this. Six coeval AI stars near the centre of the larger arc (called Quadrant, radius 280 pc) were suggested to be the remnants of an association, including O-stars, which swepted up the gas in the larger region starting 30 My ago. A small cluster near the center of the smaller arc (Sextant, radius 170 pc) was proposed to be responsible for that one. The positions of various features in this region are shown in Figure 1 (where the Quadrant arc in near the center and the Sextant in lower right corner) and also in Efremov and Elmegreen (1998) and in Figure in Efremov (1999a).

These centralized stellar sources of pressure could produce both young stellar arcs at the right time and position, as Efremov and Elmegreen (1998) demonstrated, yet the general picture is still not satisfactory. The main questions remaining are (Efremov, 1999a,b): (1) why are there no giant stellar arcs or rings around other, even much more rich, clusters in the LMC, (2) why are all of the stellar arcs in the LMC close to each other and why are they in only this area, (3) why are there just arcs and not full stellar rings, and (4) why are these arcs in the region of the largest and deepest HI hole in the LMC?

We believe that points 1 and 2 above are already uncompatible with assumption that a dozen or a few dozen of SNe in clusters in centers of the arcs could produce these. What was so special with these small clusters? If there was a peculiar initial mass function, why just for clusters only in this region - more so because just there exist also the Third arc and probably even one more, the Fourth arc. We imagine that smaller scale Nebulae and SNRs whose rings resemble giant stellar arcs are the young miniature example of large sized GRB and SGRs relics.

There is increasing evidence for general absence inside the HI supershells of the clusters rich enough to contain the O-stars and SNe to trigger the formation of supershells. Recently the special photometric search for clusters, which could produce the supershells in the irregular galaxy Ho II was carried out by Rhode et al. (1999). They found only 6 of total 44 supershells cases of the presence of clusters (assuming the normal IMF and age) which could contain SN/O stars numerous enough to form the observed supershells, These authors stressed that among the most sure cases of supershells without putative clusters there are just supershells the most energetic in Ho II; moreover, these supershells are within the low density regions of the galaxy where the presence of massive clusters is improbable.

The recent identification of GRB afterglows (understood as beamed jet tails) in distant galaxies has led to suggestion that they can produce very large shells and trigger star formation (Efremov, Elmegreen and Hodge, 1998; Perna and Loeb, 1998, Efremov, Ehlerova and Palous, 1999). These suggestion explained the enigmatic supergiant HI shells without a central cluster or evidence of an extragalactic cloud impact in the triggered region. The samples of large energetic supershells in galaxies with no clusters or evidences for the cloud impacts are mentioned in papers, referred to above. Also, Rhode et al. (1999) noted that practically no high velocity clouds exists around Ho II galaxy which might have been able to form supershells.

We suggest here that supershell may exist also from accumulated jet activity, which probably started with eventual SN birth explosion.

4. The origin of the GRB progenitors.

The occurrence of all stellar arcs in the LMC near each other may be explained by the common origin of the progenitors of their paternal GRB which formed in and then escaped from a massive near-by cluster. This is compatible with the common assumption that explosions of some GRBs are the result of mergering of components of close binaries that include a neutron star or black hole. These close binaries might be formed in stellar encounters inside a dense massive cluster and then escape from it. There is indeed such a cluster in the region under consideration (Efremov, 1998, 1999; Efremov and Elmegreen, 1998b). NGC 1978 is within 0.5 - 1.5 kpc from the arcs and the center of the LMC4 supershell. The age of this cluster is about 2 Hyr (Bomans et al. 1995), and it is the richest cluster of such an age in the LMC. Its mass is 0.4 - 1.4 millions of suns (Meylan et al. 1991) and it has a few hundred red giants with masses of around 1.5 suns.

The high rate of occurrence of X-ray binaries (with one component a neutron star) inside dense globular clusters is well known (e.g. Bailyn 1996). It was explained long ago as consequence of the high probability of formation of close binaries after tidal captures in the dense cluster (e.g. Fabian et al. 1975, Shklovsky 1982, Davies 1995, Phinney 1996). It was also shown (McMillan 1986) that a large number of tidally captured binaries may escape a dense old cluster as the result of three-body encounters. The comprehensive review of the data on binaries and pulsars in globular clusters (Phinney 1996) lefts no doubts that there is a lot of possibilities to form close binaries with

compact components in a cluster dense and old enough, and also that many of these binaries are able to escape from such a cluster.

There is also a special way for binaries with a neutron star component to escape from a cluster. The formation of a neutron star after a SN explosion in a binary system leads to a high kick velocity, the most likely value of which is 150 - 200 km/s (Lipunov et al. 1997). Such high velocities would spread out any future GRB over very large distances around the paternal cluster. Even much smaller velocities would disperse the GRB progenitors significantly, because the binaries may take 100 My or so before they merge to give a GRB (Lipunov et al. 1997). It is quite possible that the relics of GRB might be observed from few to hundreds parsecs from the paternal cluster.

NGC 1978 is also unusual in its extremely flattened shape (Geisler and Hodge, 1980). This may indicate a formation process involving the merger of two clusters, especially because no rotation has been detected (Fisher et al. 1992), or owing to the disk-shocking and might point to the dynamical state of the cluster which permit escaping of stars disregarding their masses - and therefore, binary stars as well.

Many binary system could escaped from this massive cluster and among them there could be the progenitors of the GRB. Hanson and Murali (1998) suggested that stellar encounters in globular clusters were able to produce not only millisecond pulsars but also binaries that evolve into GRBs.

The unique stellar arcs, the largest HI hole and the unusual cluster are not the only peculiar objects in the LMC 4 region. Near NGC 1978 there is excess number of X-ray binary stars, which include neutron star component and therefore related to GRB progenitors. Three X-ray binaries are within 20' of NGC 1978 and more are in a wider surrounding, as is evident from Haberl and Pietsch (1999). The suggested large masses of these X-ray binaries seems to be uncompatible with them being escaped from the rather old cluster, yet they might be products of the complicated evolution inside the dense cluster, including merging and/or mass exchange.

Anyway, in the same area and close to NGC 1978 is also the object which is more certain relative to GRB. It is the Soft gamma repeater (SGR), SGR0526-66, which produced the famous gamma-burst of March 5, 1979 and is within the most bright SNR in the LMC, N49. According Fargion (1998, 1999), Nakamura (1998), Dar (1999), Spruit (1999) and other workers, classical GRB left behind a soft gamma repeater (SGR) - and the only SGR known in the LMC is just here! Also in the same area, at the East end of the Qudrant arc is the millisecond X-ray pulsar A0538-66, the object of the class which is considered by Spruit (1999) as remnants of X-ray binaries that managed to escape becoming GRB. At any rate, whatever could be a reason for this, the concentration of the giant stellar arcs and GRB progenitors, relatives and relics to the same and the only region of the LMC strongly suggest that GRB and arcs are connected phenomena, and we suggested that NGC 1978 was the common source of the progenitors of GRB which produced the stellar arcs and the LMC4 supershell (Efremov 1999a,b).

The escape of the double black holes after close encounters from a dense cluster need a few Billions years (Portegies Zwart and McMillan, 1999) and this is compatible with the NGC 1978 age. Only after the ejection of the binaries with compact components from a cluster they are are close enough as to go to merging by the gravitational wave emission. This could explain why there is no X-ray binaries inside the cluster and the stellar arcs around it and these facts migt be considered the evidences that the progenitors of GRB are close wbinaries both components of which are either black hole or neutron stars (Efremov, 2000a,b).

5. Puzzling arcs properties

The properties of stellar arcs, suggested GRB relics, may say something on the nature of the GRB event. First of all this is surely the opening angle of the arcs, which is always smaller than 90 degree. The preliminary data on the arcs in a number of galaxies, including a dozen single arcs point to the preferred angle of 60 degree (Efremov, 2000a) yet the real angle may be much smaller, just because too short arcs are not recognized as arcs.

Another important property of the arcs is their perfect circular shape, independent on the galaxy plane inclination (Fig. 1). This means that some arcs are partial stellar shells, seen in projection, and not the rings in the plane of galaxy. The outburst far from the plane of the gas disk of the galaxy should result in the partial gas shell and owing to the vertical density gradient, the most dense part of the shell must ve turned to the galaxy plane. This partial shell looks like an arc due to the inclination of the plane of the galaxy to sky plane (Efremov et al., 1999).

The apex of such a partial shell seen in projection should always be turned either TO or OFF the line of nodes of the galaxy plane (its intersection with the sky plane). The most important for us is that this is not the case for the arcs in the LMC. The apexes of two arcs are about parallel to the line of nodes, the position angle of which is 162 grades (see Fig. 1). Therefore, the arcs were NOT formed from the isotropic outbursts outside the middle of the gas disk of the galaxy. Therefore, the open angle of the arcs reflects the beaming angle of the parent explosion, or is the largest possible angle of precession of the multi-precession narrow jets, which are able to fulfill the partial shell, forming the swepted-up gas shell and then stellar spherical partial shell, seen as an arc in projection.

In what follows we give the arguments for the latter possibility: the precessing jets with the variable angle of the precession. The idea on spinning-multi-precessing

gamma-jets was advanced already from the completely other considerations (Fargion 1994, 1995, 1998, 1999).

6. Gamma Burst and Soft Gamma Repeaters as Multi-precessing Gamma Jets

It is somehow surprising that after a decade of fireball inflation papers, at present (GRB990123, GRB990510 and GRB991226 over energetic event) there is no father or mother spending a word of regret on the decline and death of their popular isotropic model. On the contrary there is wide spread resistance to give up this misleading fireball model.

Gamma Ray Bursts as recent GRB990123 and GRB990510 emit, for isotropic explosions, energies as large as two solar masses annihilation. These energies are underestimated because of the neglected role of comparable ejected MeV (Comptel signal) neutrinos bursts. These extreme power cannot be explained with any standard spherically symmetric Fireball model. A too heavy black hole or Star would be unable to coexist with the shortest millisecond time structure of Gamma ray Burst. Beaming of the gamma radiation may overcome the energy puzzle. However any mild "explosive beam" as some models (Wang & Wheeler 1998) ($\Omega > 10^{-2}$) would not solve the jet containment at the corresponding disruptive energies. Moreover such a small beaming would not solve the huge GRBs flux energy windows ($10^{47} \div 10^{54}$ erg/sec), keeping GRB980425 and GRB990123 within the same GRB framework.

Only extreme beaming ($\Omega < 10^{-8}$), by a slow decaying, but long-lived precessing jet, may coexist with characteristic Supernova energies, apparent GRBs output and the puzzling GRB980425 statistics as well as the GRB connection with older,nearer and weaker SGRs relics. GRBs were understood up to 1998 as isotropic Fireball while SGRs are still commonly described by isotropic galactic explosions (the Magnetar model). However early and late Jet models (Fargion 1994-1998,Blackmann et all 1996) for GRBs are getting finally credit. Will be possible to accept a jet model for GRBs while keeping alive a mini fireball (based on huge magnetic field energetic budget) for SGRs? Indeed the strong SGR events (SGR1900+14, SGR1642-21) shared the same hard spectra of classical GRBs. In particular one should notice (Fargion 1999a, 1999b, 1999c), the GRB-SGR similar hard spectra, morphology and temporal evolution within GCN/BATSE trigger 7172 GRB981022 (a classical GRB) and just the 7171 GRB981022 (associated to SGR1900+14). This cornerstone link between GRB and SGR has been finally recognized by Woods et al. (Gogus et al. 1999) very recently. Nature would be quite perverse to mimic two very comparable events at the same detector, the same day, by the same energy spectra and by a comparable time structures by two totally different processes: a magnetar versus Jet GRBs. We argue here that, apart of the energetic, both of them are blazing of powerful jets (NS or BH); the jet are spinning and precessing source in either binary or in accreting disk systems. The optical transient OT of GRB is in part due to the coeval SN-like explosive birth of the jet related to its maximal intensity; the OT is absent in older relic Gamma jets, the SGRs. Their explosive memory is left around their relic nebula or plerion injected by the Gamma Jet which is running away. The late GRB OT,days after the burst, are related to the explosion intensity; it is enhanced only by a partial beaming ($\Omega \simeq 10^{-2}$). The extreme peak OT during GRB990123 (at a million time a Supernova luminosity) is just the extreme beamed ($\Omega \leq 10^{-5}$) Inverse Compton optical tail, responsible of the same extreme gamma (MeV) extreme beamed ($\Omega \leq 10^{-8}$) signal. Moreover the huge energy bath (for a fireball model) on GRB990123 imply also a corresponding neutrino burst. As in hot universe, if entropy conservation holds, the energy density factor to be added to the photon γ GRB990123 budget is at least ($\simeq (21/8) \times (4/11)^{4/3}$). If entropy conservation do not hold the energy needed is at least a factor [21/8] larger than the gamma one. The consequent total energy-mass needed for the two cases are respectively 3.5 and 7.2 solar masses. No fireball by NS may coexist with it. Jet could. Finally Fireballs are unable to explain the following key questions (Fargion 1998-1999) related to the association GRB980425 and SN1998bw (Galama et all1998):

1. Why nearest "local" GRB980425 in ESO 184-G82 galaxy at redshift $z_2 = 0.0083$ and the most far away "cosmic" ones as GRB971214 (Kulkarni et al.1998) at redshift $z_2 = 3.42$ exhibit a huge average and peak intrinsic luminosity ratio?
$$\frac{< L_{1\gamma} >}{< L_{2\gamma} >} \cong \frac{< l_{1\gamma} >}{< l_{2\gamma} >} \frac{z_1^2}{z_2^2} \cong 2 \cdot 10^5 \ \ ; \ \frac{L_{1\gamma}}{L_{2\gamma}}\bigg|_{peak} \simeq 10^7 . \quad (1)$$
Fluence ratios E_1/E_2 are also extreme ($\geq 4 \cdot 10^5$).
2. Why GRB980425 nearest event spectrum is softer than cosmic GRB971214 while Hubble expansion would naturally imply the opposite by a redshift factor $(1 + z_1) \sim 4.43$?
3. Why, GRB980425 time structure is slower and smoother than cosmic one,as above contrary to Hubble law?
4. Why we observed so many (even just the rare April one over 14 Beppo Sax optical transient event) nearby GRBs? Their probability to occur, with respect to a cosmic redshift $z_1 \sim 3.42$ must be suppressed by a severe volume factor
$$\frac{P_1}{P_2} \cong \frac{z_1^3}{z_2^3} \simeq 7 \cdot 10^7 \quad . \qquad (2)$$

The above questions remain unanswered by fireball candle model. Indeed hard defenders of fireball models either ignore the problem or, worse, they negate the same reality of the April GRB event. A family of new GRB fireballs are ad hoc and fine-tuned solutions. We believed

since 1993 (Fargion 1994) that spectral and time evolution of GRB are made up blazing beam gamma jet GJ. The GJ is born by ICS of ultrarelativistic (1 GeV-tens GeV) electrons (pairs) on source IR, or diffused companion IR, BBR photons (Fargion,Salis 1998). The beamed electron jet pairs will produce a coaxial gamma jet. The simplest solution to solve the GRBs energetic crisis (as GRB990123 whose isotropic budget requires an energy above two solar masses) finds solution in a geometrical enhancement by the jet thin beam. A jet angle related by a relativistic kinematics would imply $\theta \sim \frac{1}{\gamma_e}$, where γ_e is found to reach $\gamma_e \simeq 10^3 \div 10^4$ (Fargion 1994,1998). At first approximation the gamma constrains is given by Inverse Compton relation: $< \epsilon_\gamma > \simeq \gamma_e^2 \, kT$ for $kT \simeq 10^{-3} - 10^{-1} \, eV$ and $E_e \sim GeVs$ leading to characteristic X-γ GRB spectra. However an impulsive unique GRB jet burst (Wang & Wheeler 1998) increases the apparent luminosity by $\frac{4\pi}{\theta^2} \sim 10^7 \div 10^9$ but face a severe probability puzzle due to the rarity to observe even a most frequent SN burst jet pointing in line toward us. Viceversa one must assume a high rate of GRB events ($\geq 10^5$ a day larger even than expected SN one a day). Most authors today are in a compromise: they believe acceptable only mild beaming ($\Omega >\sim 10^{-3}$), taking GRB980425 out of the GRB "basket". On the contrary we considered GRBs and SGRs as multi-precessing and spinning Gamma Jets and the GRB980425 an off-axis classical jet. In particular we considered (Fargion 1998) an unique scenario where primordial GRB jets decaying in hundred and thousand years become the observable nearby SGRs. Sometimes accretion binary systems may increase the SGRs activity. The ICS for monochromatic electrons on BBR leads to a coaxial gamma jet spectrum(Fargion & Salis 1995,1996,1998): $\frac{dN_1}{dt_1 \, d\epsilon_1 \, d\Omega_1}$ is

$$\epsilon_1 \ln \left[\frac{1 - \exp\left(\frac{-\epsilon_1 (1-\beta\cos\theta_1)}{k_B \, T \, (1-\beta)}\right)}{1 - \exp\left(\frac{-\epsilon_1 (1-\beta\cos\theta_1)}{k_B \, T \, (1+\beta)}\right)} \right] \left[1 + \left(\frac{\cos\theta_1 - \beta}{1 - \beta\cos\theta_1} \right)^2 \right] \quad (3)$$

scaled by a proportional factor A_1 related to the electron jet intensity. The adimensional photon number rate (Fargion & Salis 1996) as a function of the observational angle θ_1 responsible for peak luminosity (eq. 1) becomes

$$\frac{\left(\frac{dN_1}{dt_1 \, d\theta_1}\right)_{\theta_1(t)}}{\left(\frac{dN_1}{dt_1 \, d\theta_1}\right)_{\theta_1 = 0}} \simeq \frac{1 + \gamma^4 \, \theta_1^4(t)}{[1 + \gamma^2 \, \theta_1^2(t)]^4} \, \theta_1 \approx \frac{1}{(\theta_1)^3} \quad . \quad (4)$$

The total fluence at minimal impact angle θ_{1m} responsible for the average luminosity (eq. 1) is

$$\frac{dN_1}{dt_1}(\theta_{1m}) \simeq \int_{\theta_{1m}}^{\infty} \frac{1 + \gamma^4 \, \theta_1^4}{[1 + \gamma^2 \, \theta_1^2]^4} \, \theta_1 \, d\theta_1 \simeq \frac{1}{(\theta_{1m})^2} \quad . \quad (5)$$

These spectra fit GRBs observed ones (Fargion & Salis 1995). Assuming a beam jet intensity I_1 comparable with maximal SN luminosity, $I_1 \simeq 10^{45} \; erg \, s^{-1}$, and replacing this value in adimensional A_1 in equation 3 we find a maximal apparent GRB power for beaming angles $10^{-3} \div 3 \times 10^{-5}$, $P \simeq 4\pi I_1 \theta^{-2} \simeq 10^{52} \div 10^{55} erg \, s^{-1}$ within observed ones. We also assume a power law jet time decay as follows

$$I_{jet} = I_1 \left(\frac{t}{t_0} \right)^{-\alpha} \simeq 10^{45} \left(\frac{t}{3 \cdot 10^4 s} \right)^{-1} \; erg \, s^{-1} \quad (6)$$

where ($\alpha \simeq 1$) able to reach, at 1000 years time scales, the present known galactic microjet (as SS433) intensities powers: $I_{jet} \simeq 10^{38} \; erg \, s^{-1}$. We used the model to evaluate if April precessing jet might hit us once again. It should be noted that a steady angular velocity would imply an intensity variability ($I \sim \theta^{-2} \sim t^{-2}$) corresponding to some of the earliest afterglow decay law.

7. The GRB980425-GRB980712 repeater

Therefore the key answers to the above puzzles (1-4) are: the GRB980425 has been observed off-axis by a cone angle wider than $\frac{1}{\gamma}$ thin jet by a factor $a_2 \sim 500$ (Fargion 1998) $\theta \sim \frac{500}{10^4} \approx \frac{5 \cdot 57^0}{100} \approx 2.85^0 \left(\frac{\gamma}{10^4}\right)^{-1}$, and therefore one observed only the "softer" cone jet tail whose spectrum is softer and whose time structure is slower (larger impact parameter angle). A simple statistics favoured a repeater hit. Indeed GRB980430 trigger 6715 was within 4σ and particularly in GRB980712 trigger 6917 was within 1.6σ angle away from the April event direction. An additional event 15 hours later, trigger 6918, repeated making the combined probability to occur quite rare ($\leq 10^{-3}$). Because the July event has been sharper in times ($\sim 4 \, s$) than the April one ($\sim 20 \, s$), the July impact angle had a smaller factor $a_3 \simeq 100$. This value is well compatible with the expected peak-average luminosity flux evolution in eq.(6,4): $\frac{L_{04 \, \gamma}}{L_{07 \, \gamma}} \simeq \frac{I_2 \, \theta_2^{-3}}{I_3 \, \theta_3^{-3}} \simeq \left(\frac{t_3}{t_2}\right)^{-\alpha} \left(\frac{a_2}{a_3}\right)^3 \leq 3.5$ where $t_3 \sim 78 \; day$ while $t_2 \sim 2 \cdot 10^5 \, s$. The predicted fluence is also comparable with the observed ones $\frac{N_{04}}{N_{07}} \simeq \frac{< L_{04 \, \gamma} >}{< L_{07 \, \gamma} >} \frac{\Delta\tau_{04}}{\Delta\tau_{07}} \simeq \left(\frac{t_3}{t_2}\right)^{-\alpha} \left(\frac{a_2}{a_3}\right)^2 \frac{\Delta\tau_{04}}{\Delta\tau_{07}} \geq 3$.

8. The SGRs hard spectra and their GRB link

Last SGR1900+14 (May-August 1998) events and SGR1627-41 (June-October 1998) events did exhibit at peak intensities hard spectra comparable with classical GRBs. We imagine their nature as the late stages of jets fueled by a disk or a companion (WD,NS) star. Their binary angular velocity ω_b reflects the beam evolution $\theta_1(t) = \sqrt{\theta_{1m}^2 + (\omega_b t)^2}$ or more generally a multi-precessing angle $\theta_1(t)$ (Fargion & Salis 1996) which keeps memory of the pulsar jet spin (ω_{psr}), precession by the binary ω_b and additional nutation due to inertial momentum anisotropies or beam-accretion disk torques (ω_N). On average, from eq.(5) the gamma and afterglow decays as t^{-2}; the complicated spinning and precessing jet blazing is responsible for the wide morphology of GRBs and SGRs as

well as their internal periodicity. In conclusion the puzzles for GRB980425-GRB971214 find a simple solution within a precessing jet: The different geometrical observational angle might compensate the April 1998 low peak gamma luminosity (10^{-7}) by a larger impact angle which compensates, at the same time, its statistical rarity ($\sim 10^{-7}$) its puzzling softer nature and longer timescales. Such precessing jets may explain (Fargion & Salis 1995) the external twin rings around SN1987A. We predicted its relic jet to be found in the South-East due to off-axis beaming acceleration. Jets may propel and inflate plerions as the observed ones near SRG1647-21 and SRG1806-20. Optical nebula NGC6543 ("Cat Eye") and its thin jets fingers (as Eta Carina ones), the double cones sections in Egg Nebula CRL2688 are the most detailed and spectacular lateral view of such jets "alive". Their blazing in-axis would appear in our galaxy as SGRs or, at maximal power at their SN birth at cosmic edges, as GRBs.

9. The Morphology of Precessing Jet relics

The Gamma Jet progenitor of the GRB is leaving a trace in the space : usually a nebulae where the nearby ISM may record the jet sweeping as a three dimensional screen. The outcomes maybe either a twin ring as recent SN1987A has shown, or helix traces as the Cat Eye Nebula or more structured shapes as plerions and hourglass nebulae. How can we explain within an unique jet model such a wide diversity?

We imagine the jet as born by a binary system (or by an asymmetric disk accreting interaction) where the compact companion (Bh or NS) is the source of the ultra relativistic electron pair jet (at tens GeV. Inverse Compton Scattering on IR thermal photons will produce a collinear gamma jet at MeV). The rarest case where the jet is spinning and nearly isolated would produce a jet train whose trace are star chains as the Herbig Haro ones (Fargion, Salis 1995). When the jet is modified by the magnetic field torque of the binary companion field the result may be a more rich cone shape. If the ecliptic lay on the same plane orthogonal to the jet in an ideal circular orbit than the bending will produce an ideal twin precessing cones which is reflected in an ideal twin rings (Fargion,Salis 1995). If the companion is in eccentric orbit the resultant conical jet will be more deflected at perihelion while remain nearly undeflected at a aphelion. The consequent off-axis cones will play the role of a mild "rowing" acceleration able to move the system and speed it far from its original birth (explosive) place. Possible traces are the asymmetric external twin rings painted onto the spherical relic shell by SN1987a. Fast relics NS may be speeded by this processes (Fargion, Salis 1995a, 1995b, 1995c). Because of momentum conservation this asymmetric rowing is the source of a motion of the jet relic in the South-East direction. In extreme eccentric system the internal region of the ring are more powered by the nearby encounter leading to the apparent gas arcs. If the system is orbiting in a plane different from the one orthogonal to the jet the outcoming precessing jet may spread into a mobile twin cone whose filling may appear as a full cone or a twin hourglass by a common plerion shape. At late times there is also possible apparent spherical shapes sprayed and structured by a chaotic helix. External ISM distribution may also play a role enhancing some sides or regions of the arcs. The integral jet in long times may mimic even spherical envelopes but internal detailed inspection might reveal the thin jet origin (as in recent Eta Carina string jets). Variable nebulae behaviours recently observed are confirming our present scenario.

10. Would SS433-like objects trigger star formation?

There are example objects with energetic relativistic jets in our own Galaxy - the microquasars and the object SS433. The existence of such mini-precessing jets was the first starting point (Fargion 1994) in understanding the jets blazing role in SGR-GRB. The recent HI data for the latter did prove that the accumulated energy of its jet is large enough (Dubner et al., 1998). These authors found the HI shell around SS433 with the velocity of expansion of about 76 km/s and the radius 1.1 degree (56 pc if the distance is 3 kpc) and evaluated the kinetic energy transferred to the surrounding medium to be $\sim 2 \cdot 10^{51}$ erg. They concluded that the input of kinetic energy from the jets of SS433 being $\sim 10^{39}$ ergs/s (Margon 1984) and the life-time being $\sim 2 \cdot 10^4$ yr (Zealey et al. 1980), the total energy injected by jets is $\sim 10^{51}$ ergs. This is just compatible with energy which was necessary to swept-up the gas and produce the LMC4 arcs (Efremov and Elmegreen 1998). Moreover, this jet may well last still longer. The total mass of HI which was swepted-up by SS433 is $\sim 30\ 000\ M_\odot$. It is quite possible that later on the star formation will start there. Anyway, there is the suggestion that SS433 is the precursor of a GRB (Pugliese et al. 1999).

Objects of the Galaxy known as microquasars have also powerful relativistic jets, which may have kinetic energy reaching 10^{43} ergs; there are some indication of induced star formation at the jet ends (Rodriguez and Mirabel, 1998) These objects are surely binary stars with compact component and X-ray sources; 9 such events are known in the Galaxy and thus are presumed relatives to the GRBs and SGRs. These long acting jets may well be the trigger of star formation in the pre-existing or in the swepted-up gas, and the stellar arcs may indicate the latter case.

The analogous star formation induced by jets from the active galactic nuclei is well known phenomenon. The nearest example of such event is in Cen A galaxy (Graham, 1998). One of us (DF) believes that similar precessing jets links AGN to GRB and SGRs.

11. Conclusions

The concentration of the giant stellar arcs and plausible GRB progenitors (or at least their close relatives) to the same and the only region of the LMC, the same in which the only (in the LMC) SGR is located, strongly suggests that GRB and the arcs are genetically connected phenomena. The giant arcs are plausibly the stellar remnants of GRB events. One way to produce these events is merging in compact binary systems and there is suggestion that ejections of such binaries from the dense old cluster NGC 1978 explain the concentration of all these objects in the LMC4 region. At any rate, there should be the common source of the multiple arcs nearby. The hardening (i.e. shortening the orbital period) leading to the heating the stars and the final ejection of close binary stars from a dense cluster is a process generally assumed in studies of the dynamical evolution of star clusters. The close binaries of two compact objects are formed in a dense cluster and seems to be unavoidable ejected from it during a few Billions years, before getting hardening sufficient enough for the subsequent merging, which need at least millions year more in emission of the gravitational waves (Portegiez Zwart and McMillan, 2000). It is therefore possible to suggest that X-ray emission and more so the GRB event (in the merging of two compact objects) can arise only after ejection, thus explaining the absence of X-ray source in NGC 1978 itself, as well as the absence of the stellar arc centered on the cluster (Efremov 1999, 2000).

The orientation of apexes of stellar arcs in the LMC suggests that the arc-like shapes are not due to the outburst outside the middle of the gas disk, i.e. the vertical density gradient (Efremov et al. 1999). The stellar arcs in the LMC, in NGC 6946 and other galaxies are always perfectly round and the only explanation is that they are parts of spherical shells. These two features could be explained with two possibilities: the events which triggered star formation in the partial shells were either the collimated (at the opening angle about 60 - 90 degree) superexplosions or these shells resulted from the narrow precessing jets, the precession angle being variable and its maximal value being 60 - 90 degree. As the data on the HI shell around SS433 and also on the mini-quasars in the Galaxy demonstrate, the long standing stellar jets may form a gas shell large enough. The regions of star formation, triggered in such an way may be numerous enough, because depending on the density fluctuations of the surrounding gas and especially on the projection angles, they might not look like the stellar arcs (Efremov, 1999, 2000).

If the SGR, three or four stellar arcs and supershell LMC4 in the LMC are really the imprints of GRB, we have five or six GRB events or peak activities of a slow motion SGR in the LMC during last 30 or so Myrs. This seems to be in contradiction with the high frequency of GRB-SN events suggested by the possibility that they are narrow jets, yet it is possible that most of these arise far from the gas disk of a galaxy (merging in the binary with compact components may occurs in Billions years after its formation in the galaxy disk and their velocity may be as high as 100 km/s or so, e.g. Lipunov et al. 1997) or at least in the low density areas where the probability for a jet to meet the gas cloud is low, leading to negligible gas accumulation and small star formation.

The existence of the stellar arcs give the strong support to the possibility that the GRB as well as SGR events are connected with the multi-precessing narrow jets, first suggested by Fargion (1994, 1995, 1998, 1999).The Gamma Jet energetic , triggered by an inner Comptonizing electron pairs jet, lead to GRBs spectra (Fargion,Salis 1995-1998)and observed variable morphology. New evidences favor the same SN1987A external twin rings as been relics of a precessing or multi-precessing jet. There are wider consensus today on the GRB-SN-Jet connection (Blackman 1996;Wang,Wheeler;1998; Dar 1999) and the various features of the Gamma-ray light curves during the GRB events were modelled recently with the multiprecessing jets (Portegeis Zwart et al., 1999).

The surprising connection between SN-GRB and stellar arc origination favor recent evidence for GRB preferentially located in the isolated star formation regions. This regions might be triggered by SN-GRB events, progenitors of which might have had the common origin in a massive cluster near the region.

The key problems of GRB and SGR as well as stellar arcs seem to be somehow linked together and solved at once. However main open questions are still puzzling: what are the real physical processes leading to such high, laser like, collimating and powerful, SN like, astrophysical jets? Do these jet contain also a hard spectra tail extending up to ultra high GZK energy frontiers (Fargion,Mele,Salis 1999)?

Figure 1 Caption

The four giant stellar arcs in the region of the supershell LMC4 in the LMC. The arcs have the perfect circular shape, especially evident for the smallest and youngest ones. The old massive cluster NGC 1978 is surrounded by a circle.

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